With the Compliments of

WM. RIPLEY NICHOLS.

From the Report of the Sewerage Commission, Boston, 1875.

OBSERVATIONS

Composition of the Ground-Atmosphere

IN THE NEIGHBORHOOD OF

DECAYING ORGANIC MATTER.

BY

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Of the Massachusetts Institute of Technology.

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APPENDIX D.

ACCOUNT OF SOME EXPERIMENTS MADE TO DETERMINE THE COMPOSITION OF THE GROUND-ATMOSPHERE IN PROXIMITY TO DECAYING ORGANIC MATTER.

BY PROFESSOR WM. RIPLEY NICHOLS.

The locality chosen for the experiments was on the Back-bay lands, on the vacant lot next to the Institute of Technology. A pit was dug about 6 feet square and 5½ feet deep, and on May 13th it was filled to within about a foot of the top with the semi-liquid material taken from one of the manholes in the Church-street sewer. The sand and other heavier portions settled to the bottom of the pit, and, as soon as the water had soaked away sufficiently, fine clean gravel was thrown over the material; as the mass gradually became more compact, an additional quantity of gravel was thrown in, until in the course of about two weeks the pit was filled up to the level of the surrounding ground, and the top of the deposit was about 18 inches below the surface. In order to obtain air for examination there were inserted into this covering of gravel two glass tubes, one (A) to a depth of 14 inches from the surface of the ground, another (B), to the depth of 8 inches. Owing to the yielding nature of the buried matter and to the fact that the covering continued to settle slowly, it is not possible to state just how far above the top of the decomposing mass the glass tubes ended; we may say that the bottom of the tube A was within some 6 inches, of the tube B within some 12 inches. On Sept. 13, the surface of the ground having sunk some 3 inches, that quantity of gravel was thrown upon it. I may add that the spot where the experiments were conducted was covered by a shed somewhat loosely constructed, so that there was a free circulation of air above the ground. Further, the level of the ground-water is at this place generally from 4 to 5 feet below the surface.

As to the composition of the matter which was buried, it was difficult to obtain a fair sample of the whole, but some of the upper portion of the deposit, on examination, gave moisture 69 per cent.;

ammonia, about $\frac{7}{10}$ of one per cent.; sulphuretted hydrogen expelled by boiling with water, about $\frac{1}{10}$ of one per cent. Some of the material after being dried at the temperature of boiling-water, was found to contain 0.46 per cent. of nitrogen. When the pit had been filled, and before the covering of gravel was thrown in, there was, at first, little disagreeable odor, but when the mass was covered it was undergoing decomposition, and had become somewhat offensive; bubbles of gas were escaping in some abundance. Beside the glass tubes already mentioned, which were intended to give the means of drawing air from different depths, a third tube (C) was connected with a glass funnel, which funnel was placed upon the surface of the ground, near the other tubes.

On the 5th of June the examination of the air in the soil and at the surface of the ground was begun, and examinations have been made at intervals until the present date (Nov. 10). The general results of the examinations may be summed up as follows: The gaseous products of decay which might be expected to be produced from such a mixture of animal and vegetable matter are sulphuretted hydrogen, ammonia, carbonic acid and marsh-gas; the first, sulphuretted hydrogen, was not detected even in the air taken 14 inches from the surface of the ground, *i. e.*, less than 6 inches from the top of the decaying matter; ammonia was not found in any appreciable amount; there seemed to be a small amount of marsh-gas formed (see below), and of carbonic acid a very large quantity was produced. The amount of carbonic acid was greatest in the neighborhood of the decaying matter, and decreased in amount towards the surface of the ground. The maximum amount was observed during July and August; observations made since the first of October show that the amount is steadily decreasing. Also, since the first of October marsh-gas has not been observed in the ground-atmosphere. At no time was the air in the shed a few feet from the ground observed to be in any way affected, and, indeed, this would be expected, as the gas arising from the surface of the ground and diffusing into the surrounding atmosphere would be so diluted as to escape observation.*

The determinations of carbonic acid were made by passing a

* For an illustration of the rapidity of the diffusion of carbonic acid gas, see certain observations of Pettenkofer, quoted in the Sixth Annual Report of the Mass. State Board of Health (1875), page 224.

measured quantity of air through baryta-water of known strength, and determining the amount of baryta remaining as hydrate by titration, in the usual manner. The amounts found are indicated in the following table, where are introduced also, for the sake of comparison, some determinations of the amount of carbonic acid in the gravel of the Back bay, at the depth of 10 feet (Tube D).*

Amount of Carbonic Acid expressed in number of volumes in 1,000 volumes of Air.

Date.	**Tube A.** Air taken 14 inches from surface of ground.	**Tube B.** Air taken 8 inches from surface of ground.	**Tube C.** Air taken at surface of ground.	**Tube D.** Air taken at a depth of 10 feet from the surface of ground in another locality.
June 5	87.79	52.49	....	....
7	....	....	12.40	....
12	93.34	63.80	13.05	....
18	....	....	....	7.58
19	96.41	59.65	20.34	....
25	....	....	....	15.28
26	113.76	75.41	20.85	....
July 5	122.85	....	25.56	....
8	....	....	....	15.79
16	119.54	....	....	....
17	....	....	23.13	....
Aug. 4	112.33	....	..	....
5	....	....	21.78	....
15	....	....	....	14.66
21	116.14	....	22.19	....
Oct. 1	....	....	....	8.16
5	75.60	....	6.69	....
9	66.70	....	6.12	....
16	62.33	....	5.56	....
Nov. 8	....	....	....	4.22
10	30.93	....	3.54	....

Note. — The amount of carbonic acid ordinarily present in the air may be taken as from 3 to 4.5.

* For a description of the locality from which this air is taken, and for an account of eterminations previously made at the same spot, see the Sixth Annual Report of the State Board of Health (1875), page 215.

On several occasions more complete examinations of the air were made with the following results: * —

Tube H (14 inches from the surface).

	June 21.	June 26.	Oct. 16.	Nov. 10.
Oxygen,	14.76	13.49	15.39	16.95
Carbonic acid,	11.51	13.28	6.28	2.82
Nitrogen,	73.73†	73.23†	78.44	79.23
	100.00	100.00	100.00	100.00

Tube C (at surface of ground).

	Oct. 16.	Nov. 10.
Oxygen,	19.595	19.798
Carbonic acid,	0.614	0.387
Nitrogen,	79.791	70.815
	100.00	100.00

The evidence of the presence of marsh-gas in the air of the gravel overlying the decomposing matter is as follows: A stream of the air from the tube A, after being thoroughly dried and freed from carbonic acid, was passed through a heated glass tube containing oxide of copper (previously thoroughly ignited in a stream of dry air free from carbonic acid). The air issuing from the tube was found to contain both water and carbonic acid, which, under these circumstances, must have come from the combustion of some compound or compounds containing carbon and hydrogen. We might naturally expect marsh-gas to be present, and when the amount of water formed was determined by absorption in chloride

* These determinations were made with a modified form of Doyère's gas apparatus, as described by C. W. Hinman, Amer. Jour. Sci. (3) viii. (1874), page 182. To test the accuracy of the apparatus the following examinations were made of out-door air: —

	I.	II.	III.	IV.	Normal air about
Oxygen and Carbonic acid,	20.964	20.793	20.799	20.914	Oxygen, 20.96 Carbonic acid, 0.04
Nitrogen,	79.036	79.207	79.201	79.086	Nitrogen, 79.00
	100.000	100.000	100.000	100.000	100.00

The apparatus would seem to give results sufficiently accurate for this purpose, except that for small amounts of carbonic acid the results are less accurate than those obtained by the baryta method. The oxygen was determined by absorption with alkaline pyrogallate.

† Including a small amount of marsh-gas.

of calcium, and the carbonic acid by means of standard baryta, it was found that the amounts of carbon and hydrogen were nearly in the proportion in which they exist in marsh-gas; the agreement was as close as could be expected in the case of such small quantities.*

The results of the testing for marsh-gas are as follows: —

Tube.	Date.	Amount of air taken expressed in cubic centimeters	Weight of Carbon found expressed in milligrams.	Weight of Hydrogen found expressed in milligrams.	Weight of marsh-gas calculated from the carbon found.	Volume of marsh-gas in 1,000 parts of air taken
A (14 inches from surface of ground),	June 24.	2340	7.00	2.50	8.17	5.26
	July 1.	2000	11.61	3.90	13.55	10.28
	Aug. 26.	4300	2.27	0.66	2.65	0.92
	Oct. 9.	2000	0	0	0	0
C (at surface of ground),	June 24.	3000	Trace.	. .	. .	Trace.
Outer air (in shed),	June 24.	3000	0	0	0	0

In the foregoing examinations and in those detailed in Appendix F, to follow, I have been aided by my assistant, Mr. W. E. Nickerson, and by Mrs. R. H. Richards, my indebtedness to whom I take pleasure in here acknowledging.

WM. RIPLEY NICHOLS.

* Of course other hydrocarbons, if present, would act similarly, and if carbonic oxide were present it would by this method of analysis be burned and appear as carbonic acid. Carbonic oxide has been stated to be among the products of the decomposition of organic matter. (Eulenberg. Lehre von den schädlichen und giftigen Gasen. Braunschweig, 1865, p. 30.) Boussingault (Comptes Rendus, liii. 1861, p. 862) asserts that carbonic oxide (with marsh-gas) is given out by the leaves of certain plants, especially by water-plants, under the influence of sunlight; and a recent writer (Kedzie, — Trans. Mich. State Med. Soc. 1875, p. 303) even suggests that carbonic oxide may be a potent factor in the miasmatic exhalations from marshes. Carbonic oxide is stated to have been found among the gases from certain foul waters; Bunsen, however (Bunsen's Gasometry, English edition, 1857, pp. 101–103), did not find it in the gases from a muddy pool, the examination of which he records, nor did Websky (Erdmann's Journ. für prakt. Chemie, xcii. pp. 65–96) find it in his examination of the gases arising from a pool in a peat bog. Under the circumstances of this particular case, I am inclined to doubt the probability of the presence of carbonic oxide; at any rate no amount at all considerable could be present without increasing the amount of carbon found as compared with the amount of hydrogen.

APPENDIX F.

The influence of sewers on the soil of cities has attracted so much attention, especially since the observations of Pettenkofer with regard to the badly-constructed sewers of Munich, that it has been thought advisable to make some experiments, to see whether *well-constructed* sewers exercised any appreciable influence in contaminating the ground atmosphere in their vicinity. As far as the observations have extended, the effect of the sewers seems to be inconsiderable, as the following notes by Professor Nichols will show. Similar results have been obtained in Munich during the past summer.

Account of some Examinations of the Ground-Atmosphere in the Neighborhood of Sewers.

For this investigation the old Roxbury sewer, on Dearborn street, was chosen as furnishing as instructive an example as could be found of a sewer which has been in use some years. The sewer was built in 1860, and the bottom is not impervious to water. A pipe was driven into the ground in the neighborhood of the sewer, and the opening of the pipe was calculated to be about a foot and a half from the sewer, and on the level with the spring of the arch. This would be ten feet from the surface of the street. Examination failed to detect sulphuretted hydrogen* or marsh-gas. Carbonic-acid determinations were made as follows: —

	Number of volumes of carbonic acid in 1,000 volumes of air.
October 6,	35.31
" 13,	34.63
November 12,	23.46

* For a description of the method of sinking the pipes see Sixth Annual Report of Mass. State Board of Health (1875), page 214. In testing for sulphuretted hydrogen the air is drawn through a *glass* pipe; for the carbonic-acid determinations a lead pipe was used in this case as being more convenient.

The following more complete examinations were made: —

	Oct. 13.	Nov. 16.
Oxygen,	17.21	19.41
Carbonic Acid,	3.36	1.59
Nitrogen,	79.43	79.00
	100.00	100.00

An examination was also made of the air in the ground near the Berkeley-street sewer (at the corner of Newbury street). In this place it was impossible, on account of the water in the ground, to draw the air from a point as close to the sewer as in the previous case. The air was actually taken about nine feet six inches from the surface of the street, and the spring of the arch of this sewer is twelve feet below the level of the street.

The examinations showed,

	Nov. 11.	Nov. 15.
Oxygen,	19.54	19.57
Carbonic Acid,	1.15	1.27
Nitrogen,	79.31	79.16
	100.00	100.00

These examinations would seem to indicate that, with the exception of an increased amount of carbonic acid, there is no evidence of the contamination of the ground atmosphere by the sewers, and it would seem highly improbable that injurious emanations from underground sewers should ever reach the air above by passing through the soil.

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